ASSESSMENT OF THE PROPOSED LORNE PARK INTAKE AND CLARKSON OUTFALL LAKE ONTARIO, 1974

1976

Ministry of the Environment

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AND

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A new water intake offshore of Lorne Park, Lake Ontario and a nearby outfall at Clarkson are planned. This study was undertaken to select suitable sites for the intake and outfall so that the sewage effluents are not transported towards the proposed intake site or other water users in the area. Water movements, and dilution and dispersion characteristics near the proposed water intake and sewage outfall locations were estimated from current meter data collected during June and July 1974.

The resultant currents varied from 0.6 to 3.2 $cm.s^{-1}$ with persistence factors of 0.15 to 0.67. The currents in the Clarkson area moved mainly towards the south and southwest and are roughly parallel to the shoreline. The one-dimensional dispersion co-efficients ranged from 0.00 to 1.55 $m^2.s^{-1}$ while the two-dimensional dispersion coefficients were between 0.05 and 3.40 $m^2.s^{-1}$. These results were considered low as compared to other computations in the coastal regions of Lake Ontario. The initial dilution due to jetting from the proposed outfall pipe (3.6 m diameter) was calculated to be negligible. A diffuser designed to increase initial dilution by mixing and to decrease buoyancy is therefore recommended.

ASSESSMENT OF THE PROPOSED LORNE PARK WATER INTAKE AND CLARKSON OUTFALL, LAKE ONTARIO, 1974

INTRODUCTION

A new 2.6 $m^3.s^{-1}$ (50 MIGD) water intake at Lorne Park, Lake Ontario (see Figure 1) is required for the South Peel Regional water system with provision of doubling the capacity at a future date. Approximately 3.6 km south of the proposed water intake site, a new waste outfall for the sewage treatment plant at Clarkson is planned with an initial and ultimate flow of 6.3 $m^3.s^{-1}$ (120 MIGD) and 16.5 $m^3.s^{-1}$ (315 MIGD) respectively. The coastal region of Lake Ontario between Etobicoke and Oakville Creek contains 10 existing or proposed water intakes or waste outfalls. It is, therefore, considered necessary to assess the effects of increased loadings due to the proposed outfall on existing water users at Clarkson and the proposed water intake at Lorne Park. Kohli (1974) selected sites for both the proposed water intake and waste outfall, based on a limited investigation. The previous study considered additional knowledge of water movements and dispersion characteristics, particularly near the proposed outfall location, as essential for the proper assessment of the new sites.

The water intake is being designed by Gore and Storrie Ltd., Consulting Engineers, based on water quality data at Lakeview, Lake Ontario. They consider the water quality in the vicinity of the proposed water intake adequate. This report discusses water transport, dilution and dispersion between the proposed intake and outfall.

As recommended by Kohli (1974), further water movement studies were conducted during summer 1974. No measurements were made during winter 1974-75 as instruments could not be installed due to the inclement weather. The present investigation was designed to (a) reveal the homogeneity or non-homogeneity of the area dynamics in the vicinity of the proposed Clarkson outfall, (b) gather more knowledge of the water movements and dispersion characteristics offshore of Clarkson, (c) investigate water movements and dispersion characteristics near the proposed Lorne Park water intake.

Great Lakes coastal processes are a complex combination of lake and local seiches, littoral drift, earth's rotation effects and thermal upwellings and downwellings. Statistical current data, near the proposed water intake and sewage outfall, were considered the most reliable method of determining the expected water transport and dispersion in the lake area. Three current instruments in the vicinity of the proposed Clarkson outfall at positions 154, 155, and 156

(see Figure 1) were operated during June and July 1974. Another instrument functioned at the Lorne Park site 152 (see Figure 1) near the proposed intake position between June and August. Statistical analysis of the data provides information on any predominant directions of water movements, net transport, periods of negligible movements, mean speed, and persistence factors. Time series analysis of data identifies periodicities resulting from the physical mechanisms in the area. The data were also used to determine the one-dimenionsal, two-dimensional and quasi-Lagrangian dispersion estimates.

METHOD

Submersible electronically recording current instruments were operated at four locations (152, 154, 155, and 156 - see Figure 1) in the coastal region of Lake Ontario offshore of Lorne Park and Clarkson. All instruments were supported by fixed towers resting on the lake bottom and operated as follows:

Location Code	Instrument Type	Instrument Depth from Bottom m	Mean Water Depth m	Period of Operation 1974
152	Geodyne 850	2.4	11.6	1 Jun to 9 Aug
154	Plessey MO21	2.1	11.9	1 Jun to 31 Jul
155	Plessey MO21	2.4	11.6	1 Jun to 31 Jul
156	Geodyne 920	2.4	13.1	1 Jun to 31 Jul

Prior to the field installation, the instruments were calibrated in the laboratory and set to record every 20 minutes. The Geodynes recorded current speed and direction averaged over 40 seconds, while the Plessey instruments registered averaged current magnitudes over 20 minutes. The Plessey meters logged current directions every 20 minutes. Proper functioning of the instruments was checked by independent drogue measurements (see Table 1). These comparisons were considered favourable indicating the satisfactory functioning of the self-recording current instruments. Spectral analysis also validates the current records if the significant spectral periods compare favourably with theoretical periodicities. As the observed periodicities compare well with the theoretical ones (see discussion later), the current records were considered acceptable.

DATA ANALYSIS

Currents

All data were pre-whitened (a numerical smoothing technique for removing erratic readings) after Blackman and Tukey (1959; pages 29, 39, 174) using binomial smoothing coefficients after Panofsky and Brier (1968; page 150). The data were divided into monthly records for each location. Each monthly record was subjected to statistical, time series and dispersion analysis.

Two-dimensional frequencies of occurrence of speed and current directions were computed and tabulated (see Appendix 1). A summary of results is presented in Table 2. The resultant currents (or the net transport vector) varied from 0.6 to 3.2 $cm.s^{-1}$ while the mean speed ranged from 3.0 to 5.0 $cm.s^{-1}$ for each monthly record. The maximum speed recorded in the monthly period varied from 10.7 to 23.3 $cm.s^{-1}$ and the persistence factors ranged from 0.15 to 0.67. The persistence factor is a measure of the tendency of the currents to have a predominant direction.

The data were resolved into hourly mean components in north-south and east-west directions. The resolved series were then subjected to a time series analysis using standard numerical techniques. The auto-spectral estimates (see Table 3) determine the distribution of variance of current speed with time. The results were smoothed by the Hanning of coefficients after Blackman and Tukey (1959; pages 34 and 171).

Water movements at any pairs of locations were compared using a spectral analysis technique called coherence. This technique identifies the time periods when the data at two locations are correlated (see Table 4).

Dispersion Estimates

Computations of dispersion coefficients from fixed point data assumes the spatial homogeneity of the velocity field and the approximate equivalence between the Eulerin and Lagrangian measurements. The dispersion computations based upon fixed point data are estimates. The confidence in these estimates is improved by cross-correlating the data from two adjacent locations (see Table 4).

One-dimensional dispersion coefficients (for 5 h) were computed for the four major direction quadrants utilizing the Markov Chain techniques (Palmer and Izatt 1971) to compare directional differences (see Table 5). The calculated mean distances (see Table 5) represent the particle travel

in 5 h in a given quadrant along with at the corresponding mean speeds and standard deviations. The dispersion coefficients are the measure of the plume spread per unit time in a given direction. The best dispersion occurs at location 155 during June for currents coming from north. Estimated mean distances travelled in 5 h along four major directions were plotted in Figure 2 for June and July to produce the expected plume. The mean distances travelled at study locations and perpendicular to the axis through sites 155, 154 and 156 were plotted for June and then joined by a smooth curve to obtain a 'dispersion band' (see Figure 2). If the material is released in the vicinity of locations 155, 154 and 156, it is likely to spread within the dispersion band.

Hourly two-dimensional dispersion estimates were computed by processing the time sequence of current measurements and subjecting them to transition probability techniques (Palmer and Izatt, 1970). Table 6 presents the successive two-hourly dispersion coefficients with appropriate initial current vectors for the transition probability matrix. The best dispersion coefficients were found at location 156 during June.

As water movements at positions 155, 154, and 156 were predominantly towards south and southwest, hourly mean distances were computed using a Markov Chain technique for currents towards the southwest. Table 7 gives an idea of the average and maximum distances that would be travelled by a particle released at the study locations (155, 154 or 156) during the month under consideration using a progressive vector plot. The average excursions varied from 0.2 to 1.4 km while the maximum excursions ranged from 0.8 to 13.0 km parallel to the shore (see Table 7 and Figure 3). Similar average excursions towards north (proposed intake location) ranged from 0.3 to 0.7 km while the maximum excursions varied from 1.8 to 2.5 km (see Figure 3).

DISCUSSION

Currents

Table 2 presents the summary of water current statistics at four locations during June, July and August. Monthly resultant currents at four sites varied from 0.6 to 3.2 $cm.s^{-1}$ with persistence factors ranging from 0.15 to 0.67. These results compare favourably with the resultant currents (1.7 to 4.3 $cm.s^{-1}$) obtained by Hamblin and Rogers (1967) in the nearshore regions of Lake Ontario. At Lakeview, Lake Ontario, Kohli and Palmer (1973) found resultant currents between 0.3 and 5.4 $cm.s^{-1}$ with persistence factors of 0.09 to 0.79. Previous study (Kohli, 1974) at the present investigation site showed resultant currents to vary from 0.3 to 2.6 $cm.s^{-1}$. Resultant currents during the present study moved towards the south and southwest at the Clarkson locations (155, 154, 156) during June and July. At the

Lorne Park site (152), resultant currents travelled towards the southwest during June, onshore during July and north during August. This shows that net transport near Clarkson was consistently towards the south and southwest while near the Lorne Park area net transport was variable in direction. At locations 154 and 155, negligible currents (less than 0.3 $cm.s^{-1}$) existed between 7 and 28 percent of the time during June and July. The currents at all sites travelled towards the resultant direction for 17 to 45 percent of the time, and opposite to the resultant direction for 6 to 17 percent of any record. The proposed intake location at Lorne Park was upstream from the suggested outfall site for 9 to 35 percent of the time during June and July. Currents from the proposed outfall site moved towards the proposed intake location for 6 to 23 percent of the time during June and July.

The statistically significant spectral periods (in hours) are presented in Table 3 for north-south and east-west directions at each site and month of the investigation. The inertial period of 17.1 h for Lake Ontario (Weiler, 1968) is observed at location 154 during June for the east-west direction. Semi-diurnal periodicities of 12 h were observed in the north-south direction during July at locations 155 and 156. 12 h periodicities are generally associated with lunar tides; 15.0 h periods observed at site 152 during July along both components and at location 156 during June (east-west direction only) may represent lakewide effects. Simpson and Anderson (1964) calculated the uninodal and binodal periods of longitudinal surface seiche of Lake Ontario as 5.41 and 2.48 h respectively. The uninodal period of 5.45 h was observed at location 152 during July and August and at site 156 during July in the east-west direction. Rockwell (1966) computed the lowest five modes of oscillation for Lake Ontario as 4.91, 2.97, 2.15, 1.63 and 1.29 h. Rao and Schwab (1974) obtained the lowest six modes as 5.10, 3.11, 2.31, 1.87, 1.78 and 1.45 h. As the theoretical results of Rockwell (1966) differ slightly from those of Rao and Schwab (1974) the theoretical modes are considered approximate only. Lowest fourth, fifth and sixth modes of Lake Ontario oscillations were observed (Table 3). The presence of periodicities in the current record indicate the influence of lake seiches, lunar tides and earth's rotation. These phenomena and wind changes are responsible for the variability in currents and dispersion in the area.

Table 4 shows that the currents at the Clarkson study area were reasonably well cross-correlated in a north-south direction. During June, currents at sites 154 and 155 were significantly cross-correlated for periods of 120.0, 60.0, 40.0, 2.03 and 2.0 h. Similar cross coherences between

locations 154 and 156 existed during June and July. However, the data showed no significant coherences in a north-south direction during July 1974 between positions 154 and 155. In view of the above, currents in the area may be considered reasonably homogeneous.

Dispersion

The 5 h one-dimensional dispersion coefficients varied from 0.00 to 1.55 $m^2.s^{-1}$. These values compare favourably with the 1973 results (0.00 to 1.90 $m^2.s^{-1}$) in the same area (Kohli, 1974). However, the disperson coefficients in the area of the present study are considered low as compared with the results (0.0 to 6.5 $m^2.s^{-1}$) in the nearshore area of Lakeview, Lake Ontario (Kohli and Palmer, 1973). The two-dimensional dispersion coefficients (see Table 6) varied from 0.05 (for 2 h) to 3.4 (for 8 h) $m^2.s^{-1}$. By employing quasi-Lagrangian techniques and the data measured for the present study, Palmer (1976) obtained quasi-Lagrangian dispersion coefficients in the north-south direction from 5.2 to 11.8 $m^2.s^{-1}$ for 1 to 10 h respectively. This compares well with the effective dispersion coefficient (4.1 to 14.0 $m^2.s^{-1}$ for 10 to 30 h) obtained by Murthy (1970) in Lake Ontario 13 km offshore.

The dilution factors (see Table 7) vary from 0.042 (24/1) to 0.009 (114/1) going towards the southwest. These are considered low compared to the dilution factors of 0.000011 to 0.0001 at Lakeview, Lake Ontario (Kohli and Palmer, 1973). For a flow of 6.3 $m^3.s^{-1}$ and the proposed 3.6 m (12 ft) diameter outfall tunnel the Fronde's Number is calculated as 3.6. For such a low Fronde's Number, no initial dilution may be expected (Rawn, 1960). In view of no initial dilution and low dilution factors due to dispersion (Table 7), a diffuser designed to improve initial mixing is strongly recommended.

The dilution factors at the proposed Lorne Park intake due to discharge at Clarkson range from 0.00006 (16160/1) to 0.000036 (27500/1) while the currents travel towards the proposed intake for 6 to 23 percent of the time (see Table 8). The maximum excursions from Clarkson towards the proposed Lorne Park intake was 2.5 km during June, which is about 1 km short of the intake. The sewage discharge in the Clarkson region should therefore, be adequately diluted before reaching the proposed intake site.

Lorne Park Water Intake

The resultant currents at locations 155, 154, and 156 were towards the southwest (i.e. away from locations 152) during June and July. The dilution factors (see Table 8) at the proposed intake site were considered adequate to maintain the water quality. In view of the above, it is recommended

the proposed water intake be located near site 152 over the rocky bottom (Kohli 1974).

CONCLUSIONS

The resultant currents at the Clarkson locations (155,154, 156) persisted towards the south and southwest directions during June and July 1974. Currents in the Clarkson area were found to be homogeneous. The resultant currents in this area varied from 0.9 to 3.2 $cm.s^{-1}$ while the persistence factors varied from 0.22 to 0.67. One and two-dimensional dispersion computations indicated low dispersion characteristics in the area compared to other nearshore areas in Lake Ontario. The calculated initial dilution due to jetting (in the absence of a diffuser) were also found negligible. With the negligible initial dilution (without diffuser) and low dispersion characteristics of the area, a diffuser designed to increase initial dilution by mixing and decrease buoyancy is considered essential.

As the currents in the Clarkson area are predominantly towards the south and southwest, waste discharge in this area will generally not travel far enough north to affect the water quality near location 152. Therefore, the proposed water intake may be located at site 152 over the rocky bottom.

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TABLE 1

DROGUE AND CURRENT METER COMPARISONS, 1974

Location Code	Date	Time Hours	Drogue		Current Meter	
			Speed $cm.s^{-1}$	Direction Coming From	Speed $cm.s^{-1}$	Direction Coming From
154	12 Jul	1415	4.0	155	4.7	170
155	12 Jul	1435	3.4	180	0.8	180
156	12 Jul	1340	0.5	120	2.0	110
154	17 Jul	1100	1.5	240	1.6	240
155	17 Jul	1120	8.9	240	2.5	210
156	17 Jul	1025	1.2	315	2.5	320

Table 2: Summary of Current Meter Results, Lorne Park and Clarkson, Lake Ontario 1974

	LOCATION								
	152			154		155		156	
	PERIOD								
	JUN 74	JUL 74	AUG 74	JUN 74	JUL 74	JUN 74	JUL 74	JUN 74	JUL 74
Resultant speed ($cm.s^{-1}$)	1.51	0.59	1.62	2.10	0.92	2.49	0.66	3.20	1.34
Resultant direction coming from 0° as North	38	124	177	41	30	20	349	59	55
Average speed ($cm.s^{-1}$)	4.43	4.05	3.54	3.12	2.48	3.86	3.03	5.86	5.00
Maximum speed ($cm.s^{-1}$)	14.51	14.02	10.67	20.79	12.53	20.86	15.29	23.33	20.54
Persistence factor*	0.34	0.15	0.46	0.67	0.37	0.65	0.22	0.55	0.27
Period of negligable speed (<0.3 $cm.s^{-1}$) - % of recording period	--	--	--	26	28	9	7	--	--
Percentage of time going in the resultant direction	45	17	22	41	13	24	19	29	23
Percentage of time going opposite to the resultant direction	8	7	8	7	17	11	16	6	9
Total no. of readings	2160	2232	623	2160	2232	2064	2208	2160	2232
Interval of readings (min)	20	20	20	20	20	20	20	20	20

*Persistence factor is a measure of the tendency of the currents to have a predominant direction.

TABLE 3: Summary of Major Spectral Periods (Hours), Lorne Park and Clarkson, Lake Ontario 1974
80 Percent Confidence Level

LOCATION CODE	PERIOD	AUTO SPECTRA OF CURRENTS NORTH-SOUTH	EAST-WEST
152	Jun 74	4.80	2.79,2.50*
152	Jul 74	15.00*,8.00,2.79*	15.00*,5.45,4.00,3.16,2.22
152	Aug 74	10.00,5.22	5.45,2.86*,2.55,2.26
154	Jun 74	3.87,2.67	17.14,9.23,6.00,4.44
154	Jul 74	13.33*,4.44*,3.64,2.93,2.31	13.33,2.86*
155	Jun 74	10.91,2.79,4.80	8.57,4.80,2.14
155	Jul 74	12.00,2.45	2.79,2.31
156	Jun 74	9.23*,2.93*,2.55,2.35	15.00,6.67,3.24,2.55,2.31
156	Jul 74	12.00*,7.50,4.44*,2.86*,2.26	5.45,2.26

*95 percent confidence level

TABLE 4

SUMMARY OF 95% SIGNIFICANT CROSS COHERENT PERIODS (h) IN NORTH-SOUTH DIRECTION AT CLARKSON, LAKE ONTARIO

Between Locations	Month (1974)	Significant Periods (h)
154 & 155	June	120.0, 60.0, 40.0, 2.03, 2.0
154 & 155	July	NONE
154 & 156	June	120.0, 60.0, 40.0, 30.0, 17.14, 15.0, 7.5, 2.2, 2.1
154 & 156	July	120.0, 60.0, 3.5, 2.31, 2.26

TABLE 5: Summary of Five Hour One-Dimensional Dispersion Characteristics
Lorne Park and Clarkson, Lake Ontario 1974

Location Code	Period 1974	Direction Coming from	Weighted Std.Dev.	Dispersion Coefficient	Mean Distance	Mean Speed
			m	$m^2.s^{-1}$	m	$cm.s^{-1}$
152	Jun	North	85.5	0.18	645	3.6
		East	55.4	0.09	394	2.2
		South	91.9	0.24	643	3.6
		West	20.8	0.01	273	1.5
152	Jul	North	51.3	0.07	729	4.1
		East	44.0	0.05	374	2.1
		South	86.0	0.21	602	3.4
		West	24.3	0.02	274	1.5
154	Jun	North	188.0	0.98	484	2.7
		East	170.3	0.81	401	2.2
		South	73.7	0.15	429	2.4
		West	10.1	0.00	137	0.8
154	Jul	North	63.0	0.11	351	2.0
		East	42.2	0.05	173	1.0
		South	54.1	0.08	353	2.0
		West	5.2	0.00	94	0.5
155	Jun	North	236.1	1.55	652	3.6
		East	74.2	0.15	284	1.6
		South	64.4	0.12	354	2.0
		West	26.9	0.02	190	1.1
155	Jul	North	81.7	0.19	651	3.6
		East	39.3	0.04	225	1.3
		South	39.3	0.04	268	1.5
		West	21.9	0.01	162	0.9
156	Jun	North	169.4	0.80	811	4.5
		East	204.0	1.16	813	4.5
		South	105.6	0.31	725	4.0
		West	24.8	0.02	468	2.6
156	Jul	North	79.5	0.18	647	3.6
		East	83.9	0.20	573	3.2
		South	58.5	0.10	598	3.3
		West	13.3	0.01	268	1.5

TABLE 6: Two-Dimensional Dispersion Coefficients, Lorne Park and Clarkson, Lake Ontario, 1974

Location Code	Period 1974	Initial State		Dispersion Coefficients (ε m^2 s^{-1}) for			
		$cm.s^{-1}$	from	2 h	4 h	6 h	8 h
152	Jun	4.50	NE	0.28	0.45	0.60	0.73
152	Jul	3.10	S	0.14	0.24	0.34	0.42
154	Jun	3.15	N	0.15	0.30	0.45	0.59
154	Jul	3.25	NE	0.04	0.08	0.11	0.14
155	Jun	3.15	N	0.15	0.31	0.47	0.63
155	Jul	4.00	N	0.05	0.10	0.14	0.18
156	Jun	6.75	NE	1.00	1.89	2.69	3.40
156	Jul	4.00	NE	0.20	0.34	0.47	0.61

TABLE 7

SOME WATER MOVEMENT CHARACTERISTICS OFF CLARKSON, LAKE ONTARIO

(Going towards southwest)

Location	Month 1974	Average Period h	Maximum Period h	Average Distance km	Maximum Distance km	Dispersion Coeff.* $m2.s^{-1}$	Dilution Factor*
155	Jun	3.2	15.0	0.52	2.46	0.85	82/1
155	Jul	2.0	6.0	0.26	0.77	0.12	25/1
154	Jun	4.7	85.0	0.72	13.00	0.90	103/1
154	Jul	2.9	19.0	0.28	1.79	0.08	24/1
156	Jun	5.3	34.0	1.44	9.17	0.98	114/1
156	Jul	2.9	14.0	0.73	3.57	0.19	37/1

*Calculated for average distance and period.

TABLE 8

EXPECTED DILUTION FACTORS AT PROPOSED LORNE PARK

WATER INTAKE DUE TO DISCHARGE AT CLARKSON, LAKE ONTARIO

Location	Month 1974	Percentage of Time Currents Travel Towards Intake	Average Current $cm.s^{-1}$	Dispersion Coefficient $m^2.s^{-1}$	Dilution Factor
155	Jun	8	3.8	0.12	21300/1
155	Jul	6	2.2	0.04	16100/1
154	Jun	13	3.4	0.15	25200/1
154	Jul	23	2.3	0.08	22300/1
156	Jun	9	5.9	0.31	27500/1
156	Jul	20	4.5	0.10	17800/1

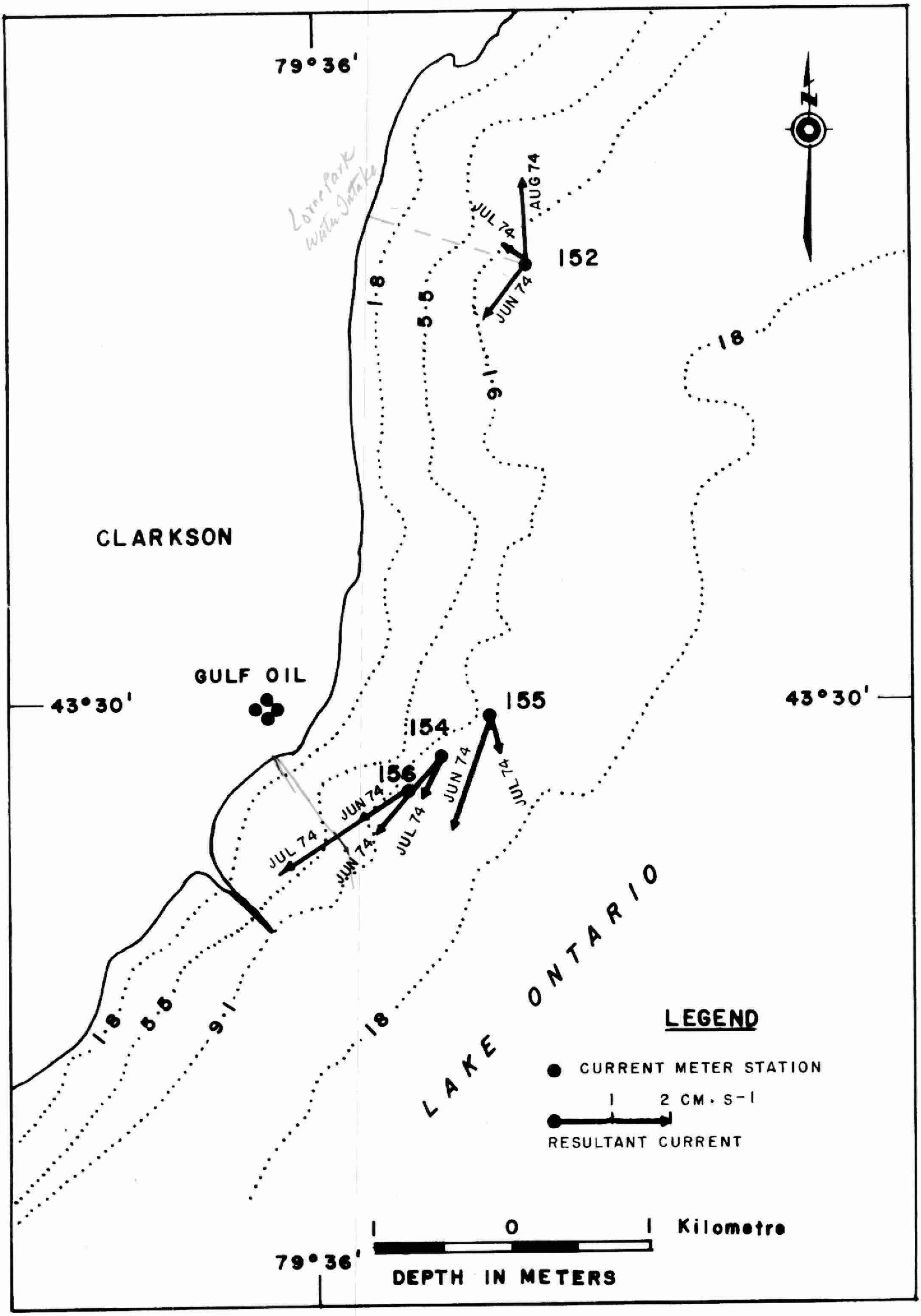

FIGURE 1: RESULTANT CURRENTS, LORNE PARK, LAKE ONTARIO

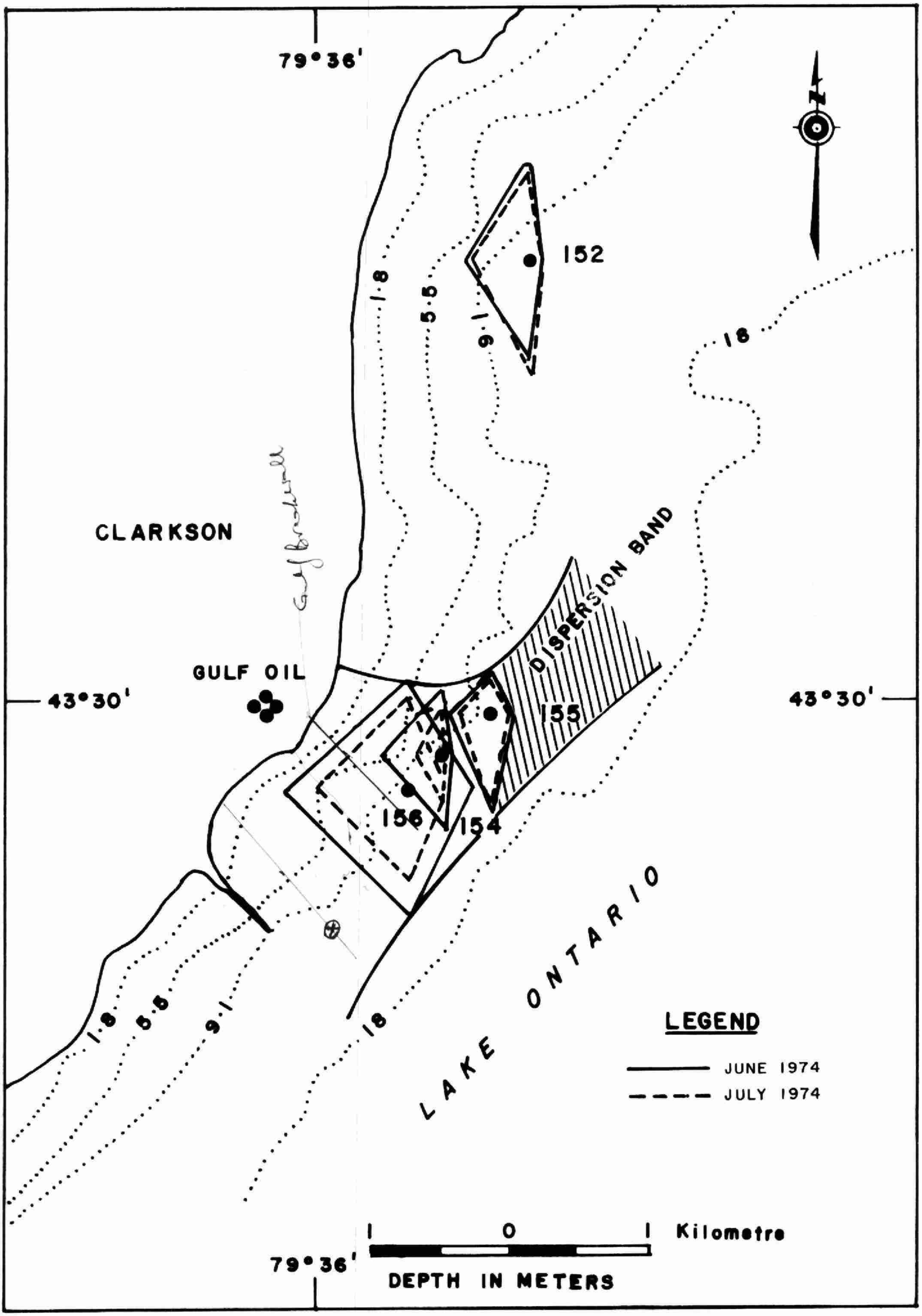

FIGURE 2: FIVE HOUR ESTIMATED PLUME, LORNE PARK, LAKE ONTARIO

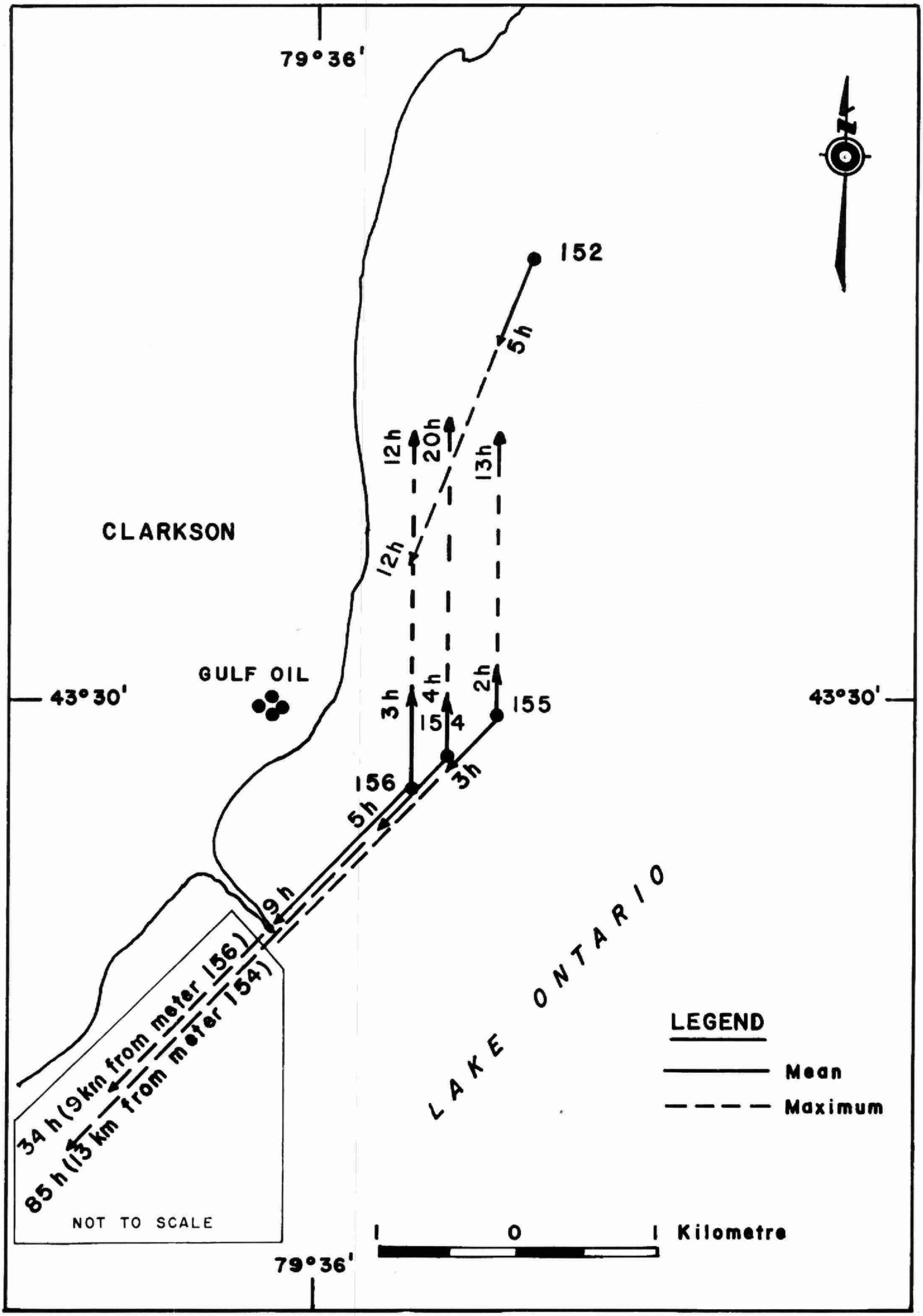

FIGURE 3: ESTIMATED STEADY WATER MOVEMENTS PARALLEL TO SHORE
LAKE ONTARIO JUNE 1974

APPENDIX I

Frequency tables (1.01 to 1.09) for the currents at locations 152, 154, 155 and 156 (Lorne Park and Clarkson regions of Lake Ontario) are presented.

Ministry of the Environment

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TABLE 1.01

LOCATION CODE: 152 (Lorne Park, Lake Ontario)

LATITUDE : 43°31'40"N

LONGITUDE : 79°35'12"W

PERIOD: JUNE 74

FREQUENCY TABLE

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES)								
	337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 - 337.49	ROW SUMS
1.00 - 1.99	3.19	3.70	3.15	2.36	3.19	2.22	1.34	2.22	21.39
2.00 - 2.99	1.99	3.38	1.57	2.03	2.96	2.31	0.60	1.44	16.34
3.00 - 3.99	1.48	2.08	1.11	3.01	3.52	2.50	0.42	1.06	15.19
4.00 - 4.99	2.41	2.69	0.93	1.20	1.94	0.83	0.74	0.60	11.34
5.00 - 5.99	3.61	3.33	0.42	1.07	2.04	0.09	0.23	0.74	11.53
6.00 - 6.99	2.13	2.59	0.09	1.07	1.71	0.00	0.00	0.93	8.52
7.00 - 14.99	7.40	5.00	0.14	0.93	1.67	0.00	0.00	0.56	15.69
COLUMN SUMS	22.22	22.78	7.41	11.71	17.04	7.96	3.33	7.55	100.00

RESULTANT CURRENT IS 1.51 $cm.s^{-1}$ AT 38 DEGREES

TOTAL NO. READINGS 2160

MEAN CURRENT IS 4.43 $cm.s^{-1}$

PERSISTENCE IS 0.34

MAXIMUM CURRENT IS 14.51 $cm.s^{-1}$

READINGS TAKEN EVERY 20 min

INSTRUMENT WAS OPERATED 2.4 m FROM BOTTOM IN 11.6 m OF WATER

Ministry of the Environment
Ontario

TABLE 1.02

LOCATION CODE: 152 (Lorne Park, Lake Ontario)

PERIOD: JUL 74

LATITUDE : 43°31'40"N

LONGITUDE : 79°35'12"W

FREQUENCY TABLE

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES)								
	337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 - 337.49	ROW SUMS
1.00 - 1.99	2.11	3.27	2.82	3.94	3.14	1.88	1.34	2.20	20.70
2.00 - 2.99	1.34	2.11	2.60	3.63	5.02	2.42	0.99	0.99	19.10
3.00 - 3.99	1.43	2.55	1.48	2.87	5.51	1.75	0.72	1.16	17.47
4.00 - 4.99	2.64	2.42	0.81	2.11	2.96	1.25	0.18	1.03	13.40
5.00 - 5.99	2.11	1.43	0.31	2.33	1.61	0.90	0.18	0.54	9.41
6.00 - 6.99	2.29	0.81	0.14	1.84	1.84	0.58	0.00	0.49	7.99
7.00 - 14.99	3.63	1.48	0.17	0.75	3.08	1.97	0.00	0.85	11.93
COLUMN SUMS	15.55	14.07	8.33	17.47	23.16	10.75	3.41	7.26	100.00

RESULTANT CURRENT IS 0.59 cm.s^{-1} AT 124 DEGREES

TOTAL NO. READINGS 2232

MEAN CURRENT IS 4.05 cm.s^{-1}

PERSISTENCE IS 0.15

MAXIMUM CURRENT IS 14.02 cm.s^{-1}

READINGS TAKEN EVERY 20 min

INSTRUMENT WAS OPERATED 2.4 m FROM BOTTOM IN 11.6 m OF WATER

Ministry of the Environment

Ontario

TABLE 1.03

LOCATION CODE: 152 (Lorne Park, Lake Ontario)

PERIOD: AUG 74

LATITUDE : 43°31'40"N

LONGITUDE : 79°35'12"W

FREQUENCY TABLE

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES) 337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 - 337.49	ROW SUMS
1.00 - 1.99	3.21	5.78	6.42	7.06	2.73	3.37	3.37	1.12	33.06
2.00 - 2.99	1.77	3.69	2.73	3.85	2.73	1.44	1.61	2.41	20.23
3.00 - 3.99	0.96	0.64	0.80	2.25	2.25	2.57	2.09	1.93	13.49
4.00 - 4.99	0.80	0.32	0.96	1.28	2.09	2.57	0.80	0.16	8.98
5.00 - 5.99	0.80	0.48	0.00	0.96	2.41	2.73	0.32	0.00	7.70
6.00 - 6.99	0.32	0.00	0.16	1.28	4.32	0.96	0.32	0.00	7.36
7.00 - 10.99	0.00	0.00	0.00	1.46	5.28	1.93	0.00	0.00	8.68
COLUMN SUMS	7.87	10.91	11.08	18.14	22.31	15.57	8.51	5.62	100.00

RESULTANT CURRENT IS 1.62 $cm.s^{-1}$ AT 177 DEGREES

TOTAL NO. READINGS 623

MEAN CURRENT IS 3.54 $cm.s^{-1}$

PERSISTENCE IS 0.46

MAXIMUM CURRENT IS 10.67 $cm.s^{-1}$

READINGS TAKEN EVERY 20 min

INSTRUMENT WAS OPERATED 2.4 m FROM BOTTOM IN 11.6 m OF WATER

Ministry of the Environment
Ontario

TABLE 1.04

LOCATION CODE: 154 (Clarkson, Lake Ontario)

PERIOD: JUN 74

LATITUDE : 43°29'42"N

LONGITUDE : 79°35'41"W

FREQUENCY TABLE

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES)								
	337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 - 337.49	ROW SUMS
0.00 - 0.30	3.47	5.32	3.56	2.87	4.40	2.45	2.59	1.57	26.25
0.31 - 1.99	2.96	5.79	2.50	1.25	3.30	3.10	1.76	1.25	21.94
2.00 - 3.99	4.58	9.54	1.39	1.44	2.08	1.25	0.46	0.42	21.16
4.00 - 5.99	3.38	6.90	0.23	0.05	1.57	0.14	0.05	0.00	12.31
6.00 - 7.99	1.11	6.67	0.05	0.00	0.56	0.00	0.00	0.00	8.52
8.00 - 9.99	0.83	3.66	0.00	0.00	0.60	0.00	0.00	0.00	5.14
10.00 - 20.99	0.56	3.47	0.00	0.00	0.65	0.00	0.00	0.00	4.68
COLUMN SUMS	16.94	41.34	7.73	5.69	13.19	6.99	4.86	3.24	100.00

RESULTANT CURRENT IS 2.10 cm.s^{-1} AT 41 DEGREES

TOTAL NO. READINGS 2160

MEAN CURRENT IS 3.12 cm.s^{-1}

PERSISTENCE IS 0.67

MAXIMUM CURRENT IS 20.79 cm.s^{-1}

READINGS TAKEN EVERY 20 min

INSTRUMENT WAS OPERATED 2.1 m FROM BOTTOM IN 11.9 m OF WATER

Ministry of the Environment

Ontario

TABLE 1.05

LOCATION CODE: 154 (Clarkson, Lake Ontario)

PERIOD: JUL 74

LATITUDE : 43°29'42"N

LONGITUDE : 79°35'41"W

FREQUENCY TABLE

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES) 337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 - 337.49	ROW SUMS
0.00 - 0.30	2.28	2.96	3.14	4.21	6.09	4.26	2.28	2.87	28.09
0.31 - 1.99	2.82	4.44	2.33	4.48	7.71	4.12	1.48	1.30	28.67
2.00 - 3.99	3.35	4.12	0.45	2.24	6.14	1.08	1.34	1.21	20.43
4.00 - 5.99	2.96	2.82	0.04	0.45	2.82	0.27	0.54	0.94	10.84
6.00 - 7.99	1.66	2.69	0.00	0.00	0.67	0.04	0.18	0.22	5.47
8.00 - 9.99	2.82	1.34	0.00	0.00	0.00	0.00	0.00	0.09	4.26
10.00 - 12.99	1.61	0.63	0.00	0.00	0.00	0.00	0.00	0.00	2.24
COLUMN SUMS	18.01	19.00	5.96	11.38	23.43	9.77	5.82	6.63	100.00

RESULTANT CURRENT IS 0.92 $cm.s^{-1}$ AT 30 DEGREES

TOTAL NO. READINGS 2232

MEAN CURRENT IS 2.48 $cm.s^{-1}$

PERSISTENCE IS 0.37

MAXIMUM CURRENT IS 12.53 $cm.s^{-1}$

READINGS TAKEN EVERY 20 min

INSTRUMENT WAS OPERATED 2.1 m FROM BOTTOM IN 11.9 m OF WATER

Ministry of the Environment

Ontario

TABLE 1.06

LOCATION CODE: 155 (Clarkson, Lake Ontario)

LATITUDE : $43^{\circ}29'52''N$

LONGITUDE : $79^{\circ}35'30''W$

PERIOD: JUN 74

FREQUENCY TABLE

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES)								ROW SUMS
	337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 - 337.49	
0.00 - 0.30	1.31	1.41	1.16	0.10	1.50	1.45	0.78	0.87	8.58
0.31 - 1.99	4.99	5.57	3.54	3.20	2.03	4.51	2.33	4.12	30.28
2.00 - 3.99	7.75	5.38	2.62	0.73	1.94	3.83	0.44	1.07	23.74
4.00 - 5.99	7.61	3.54	0.10	0.24	0.63	0.78	0.29	0.44	13.61
6.00 - 7.99	5.52	4.80	0.00	0.00	0.68	0.24	0.00	0.00	11.24
8.00 - 9.99	2.96	2.23	0.00	0.00	0.53	0.15	0.00	0.00	5.86
10.00 - 20.99	4.55	1.50	0.00	0.00	0.53	0.10	0.00	0.00	6.69
COLUMN SUMS	34.69	24.42	7.41	4.26	7.85	11.05	3.83	6.49	100.00

RESULTANT CURRENT IS 2.49 $cm.s^{-1}$ AT 20 DEGREES

TOTAL NO. READINGS 2064

MEAN CURRENT IS 3.86 $cm.s^{-1}$

PERSISTENCE IS 0.65

MAXIMUM CURRENT IS 20.86 $cm.s^{-1}$

READINGS TAKEN EVERY 20 min

INSTRUMENT WAS OPERATED 2.4 m FROM BOTTOM IN 11.6 m OF WATER

Ministry of the Environment
Ontario

TABLE 1.07

LOCATION CODE: 155 (Clarkson, Lake Ontario)

PERIOD: JUL 74

LATITUDE : 43°29'52"N

LONGITUDE : 79°35'30"W

FREQUENCY TABLE

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES) 337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 - 337.49	ROW SUMS
0.00 - 0.30	0.63	0.72	0.77	0.95	0.91	1.13	0.91	1.18	7.20
0.31 - 1.99	3.22	4.35	3.99	5.25	7.43	9.60	3.22	2.85	39.90
2.00 - 3.99	5.57	2.81	1.54	2.81	6.07	4.39	1.86	2.81	27.85
4.00 - 5.99	2.45	0.86	0.18	2.13	1.54	1.13	1.63	1.90	11.82
6.00 - 7.99	2.26	0.72	0.09	0.18	0.36	0.41	0.54	0.59	5.16
8.00 - 9.99	2.67	0.77	0.00	0.00	0.05	0.00	0.32	0.09	3.89
10.00 - 15.99	2.58	0.86	0.00	0.00	0.05	0.59	0.00	0.09	4.17
COLUMN SUMS	19.38	11.10	6.57	11.32	6.39	17.26	8.47	9.51	100.00

RESULTANT CURRENT IS 0.66 $cm.s^{-1}$ AT 349 DEGREES

TOTAL NO. READINGS 2208

MEAN CURRENT IS 3.03 $cm.s^{-1}$

PERSISTENCE IS 0.22

MAXIMUM CURRENT IS 15.29 $cm.s^{-1}$

READINGS TAKEN EVERY 20 min

INSTRUMENT WAS OPERATED 2.4 m FROM BOTTOM IN 11.6 m OF WATER

Ministry of the Environment

Ontario

TABLE 1.08

LOCATION CODE: 156 (Clarkson, Lake Ontario)

PERIOD: JUN 74

LATITUDE : 43°29'34"N

LONGITUDE : 79°35'51"W

FREQUENCY TABLE

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES)							
	337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 - 337.49	ROW SUMS
1.00 - 1.99	1.48	1.99	1.06	0.74	0.83	0.60	0.51	0.65	7.87
2.00 - 3.99	3.98	6.11	5.65	4.44	2.82	1.76	1.67	1.53	27.96
4.00 - 5.99	1.39	9.72	4.54	2.50	2.08	4.21	0.74	0.97	26.16
6.00 - 7.99	1.20	8.15	2.22	0.69	0.60	1.34	0.51	0.09	14.82
8.00 - 9.99	0.79	7.13	0.69	0.00	1.06	0.69	0.05	0.00	10.41
10.00 - 11.99	0.14	4.95	0.51	0.00	0.56	0.09	0.00	0.00	6.25
12.00 - 23.99	0.00	5.47	0.00	0.00	1.08	0.00	0.00	0.00	6.53
COLUMN SUMS	8.98	43.52	14.68	8.38	9.03	8.70	3.47	3.24	100.00

RESULTANT CURRENT IS 3.20 cm.s^{-1} AT 60 DEGREES

TOTAL NO. READINGS 2160

MEAN CURRENT IS 5.86 cm.s^{-1}

PERSISTENCE IS 0.55

MAXIMUM CURRENT IS 23.33 cm.s^{-1}

READINGS TAKEN EVERY 20 min

INSTRUMENT WAS OPERATED 2.4 m FROM BOTTOM IN 13.1 m OF WATER

Ministry of the Environment

Ontario

TABLE 1.09

LOCATION CODE: 156 (Clarkson, Lake Ontario)

PERIOD: JUL 74

LATITUDE : 43°29'34"N

LONGITUDE : 79°35'51"W

FREQUENCY TABLE

SPEED (CM/SEC.)	DIRECTION COMING FROM (DEGREES)								
	337.50 - 22.49	22.50 - 67.49	67.50 - 112.49	112.50 - 157.49	157.50 - 202.49	202.50 - 247.49	247.50 - 292.49	292.50 - 337.49	ROW SUMS
1.00 - 1.99	1.93	1.57	1.84	1.25	1.03	0.54	0.63	1.21	10.00
2.00 - 3.99	4.88	6.27	6.41	5.02	7.93	5.20	2.73	2.42	40.86
4.00 - 5.99	3.32	4.44	2.69	1.21	5.96	2.78	1.25	1.97	23.62
6.00 - 7.99	1.57	1.79	0.54	0.58	4.44	0.27	0.63	1.08	10.90
8.00 - 9.99	0.67	1.57	0.09	0.09	1.03	0.31	0.36	0.22	4.34
10.00 - 11.99	0.27	2.60	0.63	0.00	0.00	0.18	0.22	0.13	4.03
12.00 - 20.99	1.65	4.34	0.21	0.00	0.00	0.04	0.00	0.00	6.24
COLUMN SUMS	14.29	22.58	12.41	8.15	20.39	9.32	5.82	7.03	100.00

RESULTANT CURRENT IS 1.34 $cm.s^{-1}$ AT 55 DEGREES

TOTAL NO. READINGS 2232

MEAN CURRENT IS 5.00 $cm.s^{-1}$

PERSISTENCE IS 0.27

MAXIMUM CURRENT IS 20.54 $cm.s^{-1}$.

READINGS TAKEN EVERY 20 min

INSTRUMENT WAS OPERATED 2.4 m FROM BOTTOM IN 13.1 m OF WATER